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Public capital effects on spanish regions productivity: a non-parametric approach (1965-1998) *

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Abstract

This paper contributes to the empirical literature on public capital effects on Spanish regions productivity by applying an alternative approach to examine its influence based on a *non-parametric* FDH production technology with variable scaling parameters (VP-FDH) proposed in Kersten and Vanden Eeckaut (1999). This technique has significant advantages for regional comparisons of productivity and, more generally, wherever the assumption of convexity for the production set is not likely to be appropriate. My results show that public capital has a significant impact in the less developed regions. When I disaggregate public capital in the «so-called» *core* and *non-core* infrastructures I find that the first type of infrastructure have developed an important role in the majority of periods.

Keywords: cross-regions productivity, technological efficiency, public capital, convexity.

JEL Classification: C31, O47.

1. Introduction

Since the starting of EMU, the interest in studies concerned with the economic performance of European regions has considerably increased. In relation to these studies, there has been a lively policy debate in Spain and in the rest of Europe on the role that public investment programs could have in stimulating growth by affecting Total Factor Productivity (TFP, henceforth) in the private sector [1]. In this topic, the Spanish case appears to be particularly interesting because Spain suffers a marked regional heterogeneity. As it is well known, some regions of Spain lag behind the rest of the country in terms of per capita income and economic performance.

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As regards the empirical evidence for Spanish regions, a large number of papers have found support for the importance of *public* capital through the most widely adopted methodology. This approach is based on the estimation of an augmented production function for the *private* sector where *public* capital enters as an additional input beside *private* capital and *labour.* Several authors have derived the elasticity of output to *public* capital. De la Fuente (1994) was one of the pioneering papers in analysing public capital effects on productivity for Spanish regions. Later on, there were many other studies based on this approach. These include, among others, Más *et al.* (1994), Gorostiaga (1999), María-Dolores and Puigcerver (2002) and Bajo and Díaz-Roldán (2003) whose results support the evidence that the investment in public capital has had a positive effect in the GDP per head growth rate in Spanish regions. Nevertheless, this production function approach has been the target of several criticisms. The most important criticism is related to the direction of causality in the relationship between output and public capital and the use of a restrictive functional form for the production function (see Gramlich, 1994). An alternative methodology closely related to this is the one which is labelled as «growth accounting». In this case, TFP is computed as a Solow residual and is used as the dependent variable in a regression including public capital among the regressors. This methodology has also been criticised on the ground of the restrictive assumptions needed for the computation of the Solow residual.

However, a standard assumption in this literature is that public infrastructure shifts an average production function upward. Several theoretical contributions question it and suggest that at least some forms of public infrastructure are neither under the direct control of private-sector firms and it is not substitutable with private labour and capital. This assumption implies that such infrastructure capital should not be modelled as an explicit input in a production function. The infrastructure effect is given in this case by a decrease in technical inefficiency of private-sector production (see Mullen, Williams and Moomav, 1996) and this effect is difficult to capture through a direct output elasticity of public capital estimation.

On the other hand, there has been a growing interest in the application of the technical efficiency approach for Spanish regions the last years. In several papers has been estimated the production frontier and efficiency levels under both, *parametric* and *non parametric,* approaches. To name a few, Maudos *et al.* (1998, 2000) and Pedraja *et al.* (2002) analyse the convergence and growth of labour productivity, respectively, in the Spanish regions through a *non-parametric* linear programming techniques to compute Malmquist productivity indexes. In a similar pattern, Gumbau (2000) studies the contribution of technical efficiency in the period 1964-1993 and finds substantial differences among sectors as well as among regions. Finally, Salinas (2003) also analyses the productivity growth of Spanish regions over the period 1965-1995 decomposing productivity gains into technological progress and efficiency change by means of Malmquist indexes, and observes the effects of *human* and *public* capital on growth in terms of their impact on Total Factor Productivity.

As in these mentioned studies, the main goal of this paper is to test the impact of *public* capital on productivity at regional level following a production frontier approach. Unlike the majority of them, however, I allow for human capital accumulation to control the large differences in human capital endowments existing across Spanish regions. I also take into account the main criticisms levelled against the production function approach and do a non-parametric analysis of the relationship between output and public capital. For that objective, I apply a novel approach to the measurement of technical efficiency, the Free Disposal Hull (FDH henceforth) approach with variable scaling parameters introduced by Kerstens and Vanden Eeckaut (1999) to test the role of public capital on Productivity and observe the main divergences across regions. The main advantage of this FDH approach is that it does not require any assumption about the functional form and it does either require assumptions about the degree of returns to scale in the production function [2].

Accordingly, the proposed methodology in this paper provides a useful tool in order to analyse a number of issues which have been tackled within the previous methodologies in an alternative way. Those issues range from *Is public capital a primordial determinant on productivity with identical effect for all regions and all the time-periods?* to *Which component is more important inside it?* I also think that the contribution of this study may be interesting because, to my knowledge, it is the first time that indices of technological catch-up through FDH approach with variable scale parameters are applied to a sample of Spanish regions and this technique shows significant advantages for comparisons of productivity and, more generally, when the assumption of convexity for the production set is not likely to be appropriate. I apply this technique to cross-region productivity comparisons because it is an important field where the convexity hypothesis could be questioned such as I demonstrate later.

Proceeding in this way, I obtain several interesting results. First, I show that the FDH approach has more significant advantages because the assumption of convexity for the production set for Spanish regions could not be appropriate. Second, I find statistical evidence in favour of the significance of public capital. Looking carefully the previous result, I observe how the «*core*» component of infrastructures (roads, airports, harbours, railroads, water and electricity) comes out much more strongly than the «*non-core*» (education, hospitals, others). Finally, I observe that the impact of public capital is stronger in the less developed regions.

The rest of the paper is organised as follow. Section 2 introduces the FDH approach with variable scaling parameters and motivates its usefulness. Section 3 applies the non-parametric methodology to derive indices of technological catch-up for Spanish regions and discusses its main advantages. After that, in section 4, I test public capital (aggregate and disaggregated) effects and observe divergences among the Spanish regions. Finally, Section 5 makes conclusions.

2. The FDH approach with variable scaling parameters (VP-FDH)

The specification of the public capital-productivity relationship in the production function approach is usually based on a set of restrictive assumptions on the production technology, such as constant returns to scale and a given functional form. In view of these restrictions, it seems desirable to test the relevance of public capital in the production process through a very different way. In this section I rely on some recent developments of the non-parametric approach to the quantitative analysis of production such as Deprins *et al.* (1984), Tulkens (1993), Banker (1996) and Kersten and Vanden Eeckaut (1999) to ascertain whether public capital enters significantly in the production set including value added as output and labour and private capital as other inputs.

These non-parametric approaches have attracted considerable interest because they require an extremely limited number of hypothesis on the production process. In these methodologies the technical efficiency of a producer is assessed on the basis of a reference production set constructed without presupposing the existence of a functional relation between inputs and outputs.

For our aims, it is fundamental to notice that an efficiency gap in an input-output space including producers with different technologies can measure differences in their state technology and in their productivity. Thus, if some input endowments are not duly allowed for, efficiency gaps may also represent these relative lacks. If we have a look in Figure 1 we can see in the horizontal axis one input, X, and in the vertical axis the output, Y. We suppose that firms must utilise other inputs (i.e. human capital, infrastructures, social capital) beside X to produce Y. Thus, the *efficiency gap* between producer M and the production frontier can depend either on its smaller endowment in at least one of these factors, or on an inferior technology, or on its capacity to use its technology optimally. Later, the frontier analysis can be used to detect not only inefficiencies but also gaps in factor endowments and technology.

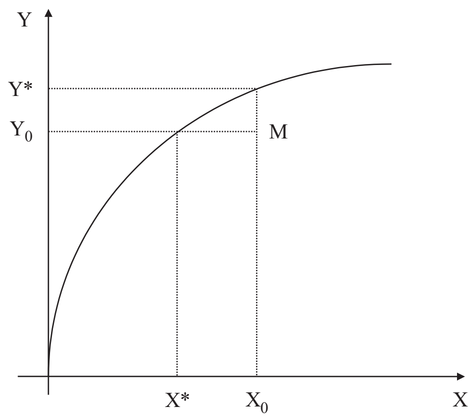

Figure 1. A simple technology example with one input X and one output Y

The non-parametric methods are divided between those imposed upon the production set hypothesis of convexity [derived from Farrell's (1957) seminal study] and usually known as Data Envelopment Analysis (DEA, henceforth) and those that do not need this assumption (the FDH approach introduced b y Deprins *et al.,* 1984 and Tulkens, 1993). In the latter case, the only requirement imposed on the production set is strong input and output availability, while in DEA the additional hypothesis of convexity is made. In FDH, for a given set of producers Y_0, the reference set $Y(Y_0)$ is characterised in terms of an observation *i,* by the following postulate:

$$(X^i, Y^i) \text{ observed}, (X^i + \alpha, Y^i - \beta) \in Y(Y_0), \alpha, \beta \geq 0$$

where α and β are vector of free disposal of input and output, respectively. In other terms, due to the possibility of free input and output availability, the reference set includes *all the producers which are using the same or more inputs and which are producing the same or less output in relation to observation i.* In Figure 2 the input-output pairs correspond with a cross-section of producers examined at a given point in time. We begin with observation *b* and define every observation located at its right and/or below (more input and the same output, like *h,* or less output and the same input, like *i,* or else with more input and less output, like *f)* as dominated *b.* On the other hand, *g* is not in the FDH reference set of producer of *b,* because it produces less output but also uses less input. This exercise is carried out for every observation and the observations dominated by other producers are considered as *inefficient.* The points *a, b, c* and *d* are not in the FDH reference set of any other producer and can be consider *efficient.* They constitute the frontier of the overall reference set. Those units which are not dominated by any other observation are considered instead as efficient producers, belonging to the frontier of the reference set.

In DEA methodology, the frontier of the overall reference set is found by constructing a convex envelope around the production set implying the assumption not only of free input and output disposal, but also of convexity. As a consequence, the DEA frontier largely consists of virtual observations made as linear combinations of some efficient producers (see dotted line in Figure 2). This feature differentiates DEA from FDH, where an *inefficient* observation is necessarily dominated by at least one other actually existing observation. Thus,

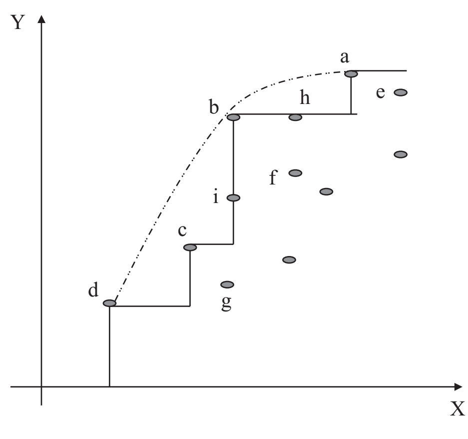

Figure 2. A FDH production frontier example

the main advantage of the FDH approach is to conduct direct comparisons between actually existing producers as it warrants a higher degree of comparability between observations. Actually, the definition of FDH reference frontier implies that an observation can belong to it without dominating any other observation. For instance, an observation like *d* is defined efficient only because it is located in an area of the production set where there are no other observations with which it can be compared.

This methodology allows us to leave behind the hypothesis of convexity of the production set. This means that if the reference set is characterised by the existence of non-convexities, the frontier obtained through FDH is likely to fit more closely the data than the one obtained through DEA. Also, the reference set is made up of actually existing units rather than by a convex hull. This implies that FDH will be less sensitive to the presence in the reference set of outliers than DEA.

With reference to the economic theory backing the DEA and FDH approach, one might ask what are the sense and the consequences of comparing, say, Baleares to a linear combination of Castilla y León and La Rioja. As I will demonstrate below, such an occurrence is far from unrealistic. More generally, it has been recently observed that in cross-regions comparisons of productivity one must rely on empirical aggregate production function frontiers obtained from unobservable micro frontiers. In this case, when the available technology includes more than one technique, a modification of the environment faced by producers may lead to changes in technique, as well as to changes in the output-input mix for a given technique. Consequently, the hypothesis of convexity may not be sustained by the observable aggregate production frontiers [3].

Anyway, one problem with the traditional FDH approach is that some observations may be efficient because they are located in an area of the production set where there are no other observations with which they can be compared *(efficiency by default).* This problem is relevant when it is employed a small data set as in our case. To solve this problem we can use a refinement of the FDH, the FDH-VP proposed by Kerstens and Vanden-Eeckaut (1999). While still relaxing the hypothesis of convexity, variable-parameter FDH imposes more structure on the production set than traditional FDH, in the sense that each observation can be compared not only to other observations, but also to their smaller or larger proportional replicas. This property makes it an interesting tool in the field of cross-country comparisons of productivity.

As a starting point in our job we explain how the FDH approach works and show its advantages that stem from its relaxing hypothesis of convexity of the production set. Next, we demonstrate VP-FDH approach advantages over DEA and traditional FDH when measuring technical efficiency across regions.

3. Measuring technical efficiency through Variable Parameter-FDH

As we have pointed out above, the VP-FDH technology introduced by Kersten and Vanden Eeckaut (1999) can improve the scope for comparability among producers and maintain a low number of assumptions about the production technology. This approach is a promising research tool where the hypothesis of convexity has been questioned.

3.1. Checking VP-FDH usefulness for a cross-regions analysis

To motivate the relevance of these mentioned considerations I apply it within the field of cross-region productivity comparisons and compare its performance to that of traditional FDH and of DEA-VRS introduced by Banker *et al.* (1984). I take cross-regions productivity comparisons because it is an important field where the convex hypothesis has been questioned.

For our purpose I rely on regional data over the period 1965-98 (bi-annual except the last four years) obtained from the BBVA foundation and IVIE. The output variable is the GVA (Gross Value Added) at 1986 prices, whereas the input variables are the capital stock (net of residential construction) at 1986 prices and the number of workers in employment [4]. I adjust labour for the regional stock of human capital. Following what is common practise in «growth accounting», we adopted the technique suggested in Hall and Jones (1999) in order to augment labour for human capital [5]. Let L_{it} stand for the number of employees in region *i* at time *t* and Z_{it} for the average number of years of education. Then, labour augmented for human capital accumulation in region *i* at time *t* can be defined by:

$$N_{it} = L_{it}\ e_{it}^{\varphi Z_{it}}$$

where φ is the coefficient on education in the Mincer earning functions. To take out the cyclical component and the noise from the data we average them over periods not shorter than five years: 1965-69, 1971-75, 1977-81, 1983-87, 1989-93 and 1995-98. The basic assumption behind this procedure is that the state of technology does not change appreciably within any one of these subsamples.

All the frontier analysis I do and all efficiency scores I derive are output-oriented. I do not claim any hard theoretical ground for this choice. Note that if we take an input orientation in a two-input space the commonly adopted Debreu-Farrell measure of efficiency may not measure technical efficiency exhaustively in the sense of Koopmans (1951). Nevertheless, as our production set includes only one output, no discrepancies between the Debreu-Farrell and the Koopmans concepts can emerge if the analysis is output-oriented, allowing us to abstract here from these measurement problems.

Adopting a widely used terminology we define as the *peer group* of a given observation the linear combination of observations constituting the frontier point to which the observation is compared. Then, a relation of dominance is the subset of observations including a given observation and its *peer group* (or its peers). We will say that a mixed relation of dominance occurs when two alternative regions appear within the same relation of dominance. Our first step is to apply the DEA technique to our sample. Table 1 offers the main results and it reflects the pervasive existence and heterogeneous composition of these mixed relations of dominance which cast doubts on the appropriateness of the convexity assumption within our study. For 1965-69 there are 2 mixed relations of dominance which mix such diverse regions as Castilla y León and Madrid. For 1971-75 there are 10 mixed relations of dominance (5 mixing Canarias-Madrid, 4 Castilla y León-Madrid and 1 Canarias-La Rioja). For 1977-81 there are 11 mixed relations of dominance (10 mixing Canarias-Castilla y León and 1 Canarias-La Rioja). During the 1983-87 we observe 13 mixed relations of dominance (all of them mixing Canarias-Castilla y León). For 1989-93, there are 9 mixed relations (mixing Castilla y León-La Rioja). Finally, for 1995-98 there are 13 mixed relations (10 mixing La Rioja-Castilla La Mancha and 3 mixing Castilla y León-La Rioja). The dominance existence and the heterogeneous composition cast doubts on the goodness of the convexity assumption within our field. Obviously, a production set spanned by the convex combination of regions so different in size and input mix as Madrid-Canarias and Cataluña-Canarias is very probably characterised by non-convexities. An additional important point is that the importance of non-convexities can change over time. In Table 1 we also can observe that the number of mixed relations of dominance does not decrease over time (2,

Table 1
Mixed relations of dominance for DEA approach

1965-69			1971-75			1977-81		
Region	**Peers**		**Region**	**Peers**		**Region**	**Peers**	
CANT	C y L	MAD	AND	CAN	LR	AND	CAN	LR
PV	C y L	MAD	ARA	CAN	MAD	AST	CAN	C y L
			BAL	CAN	MAD	BAL	CAN	C y L
			CANT	C y L	MAD	CANT	CAN	C y L
			CAT	C y L	MAD	CAT	CAN	C y L
			CV	CAN	MAD	CV	CAN	C y L
			NAV	CAN	MAD	MAD	CAN	C y L
			PV	C y L	MAD	MU	CAN	C y L
			AST	CAN	MAD	NAV	CAN	C y L
			EXT	CAN	LR	PV	CAN	C y L
						ARA	CAN	C y L
1983-87			**1989-93**			**1995-98**		
Region	**Peers**		**Region**	**Peers**		**Region**	**Peers**	
AND	CAN	C y L	AND	C y L	LR	AND	LR	CLM
ARA	CAN	C y L	ARA	C y L	LR	ARA	LR	CLM
AST	CAN	C y L	AST	C y L	LR	AST	LR	CLM
BAL	CAN	C y L	BAL	C y L	LR	BAL	C y L	LR
CANT	CAN	C y L	CANT	C y L	LR	CAN	LR	CLM
CAT	CAN	C y L	MU	C y L	LR	CAT	C y L	LR
CV	CAN	C y L	PV	C y L	LR	CV	C y L	LR
EXT	CAN	C y L	EXT	C y L	LR	EXT	LR	CLM
MAD	CAN	C y L				MAD	LR	CLM
MU	CAN	C y L				MU	LR	CLM
NAV	CAN	C y L				NAV	LR	CLM
PV	CAN	C y L				PV	LR	CLM
LR	CAN	C y L				LR	LR	CLM

10, 11, 13, 8 and 13). This result implies that there is no a weakening of non-convexities in the region of the production set relevant for Spanish regions.

Next, I rely on the traditional FDH approach and the FDH variable parameters scaling. Table 2A drops the assumption of convexity and relies on the traditional FDH approach. For the six periods, one find 2, 0, 1, 1, 1 and 0 mixed relations of dominance for 1965-69, 1971-75, 1977-81, 1983-88, 1989-93, 1995-98 periods, respectively. We also find 4, 6, 9, 12, 3 and 14 «efficient-by-default» observations, reducing the information content of the data (see Table 3).

Adopting variable-parameter FDH looks like an interesting compromise. It does not impose too high a price in terms of a priori inappropriate comparisons. There are 7, 2, 4, 7, 7 and 11 mixed relations of dominance (see Table 2B) and the scope for comparability in-

Table 2
Mixed relations of dominance for FDH and FDH-VP approach

a. FDH

1965-69		1971-75		1977-81	
AND	MAD	—		CLM	CAN
MU	BAL				
1983-87		**1989-93**		**1995-98**	
CLM	CAN	CLM	CAN	—	

b. VP-FDH

1965-69		1971-75		1977-81	
AND	MAD	AND	MAD	ARA	CAN
ARA	BAL	ARA	CAN	CANT	LR
AST	BAL	AST	LR	MU	LR
CAN	BAL			NAV	LR
CLM	LR				
CV	BAL				
GAL	BAL				
1983-87		**1989-93**		**1995-98**	
ARA	BAL	ARA	LR	AND	CAT
AST	BAL	AST	LR	ARA	CAT
CANT	LR	BAL	LR	AST	CAT
CLM	CAN	CLM	CAN	BAL	CAT
CAT	PV	CV	PV	CANT	CAT
CV	PV	GAL	CAN	CV	CAT
GAL	CAN	MU	LR	EXT	CAT
				GAL	CAT
				MU	CAT
				NAV	CAT
				PV	CAT

creases producing only 4, 4, 2, 4, 1 and 3 «efficient-by-default» observations (see Table 3). What is more, none of the mixed relations of dominance through the FDH and FDH variable parameters involve such diverse regions as Madrid and Canarias. This result enhances the economic sense and the credibility of the *efficiency scores* calculated through these methods.

Table 3
Number of efficient by default regions

Period	FDH	VP-FDH
1965-69	4	4
1971-75	6	4
1977-81	9	2
1983-88	12	4
1989-93	3	1
1995-98	14	3

3.2. Non-parametric estimates for technical efficiency

Once the VP-FDH properties have been showed, we proceed to measure technical efficiency through this approach. Table 4 offers the main scores obtained by the Spanish Comunidades Autónomas (CC.AA.). There are important differences among them. If we only consider the less developed regions we can observe how important this gap is. For that reason we split Spanish CC.AA. in two groups and calculate the mean score for objective 1 NUTS2 regions and the rest of regions. I use this criteria because the Objective 1 regions are those where the GDP is below 75% of the EU-15 average and the GDP per head is clearly related with the productivity. Our results are also offered in Table 4 where it can be observed that the differences are important. The largest difference between both groups of regions is observed during the first period (1965-69) and it is equal to 0.14. This gap reduces to 0.5 during the next two sub-periods, 1971-75 and 1983-87 and increases again up to 0.8 in the last period (1995-1998). I also offer the average mean for the Spanish Comunidades Autónomas in the last row in Table 4. Finally, the last column in Table 4 shows the average technical efficiency in each region during the whole sample period. In the last column in Table 4, we can appreciate a difference around 0.04 during the whole sample period (the score for Objective 1 regions is 0.89 and the score for the total set of regions is 0.93). These differences went down during the 1989-93 period (0.90 for Obj. 1 regions and 0.93 for the total regions). With reference to the average technical efficiency during the whole sample period, the results becomes reasonable. The highest scores are for Madrid, País Vasco and La Rioja (0.99) and the lowest for Castilla-La-Mancha (0.79) and Extremadura (0.80) [6].

With reference to the individual efficiency scores by regions I appreciate how the less developed regions generally improve their scores during the whole sample period. The regions that have experienced a decrease in their scores are: Baleares, Cantabria, Castilla y León, Cataluña, Comunidad Valenciana, Madrid, Navarra y La Rioja. I only find two Objec-

Table 4
FDH-VP efficiency scores

	1965-69	1971-75	1977-81	1983-87	1989-93	1995-98	1965-98
AND	0.83	0.95	0.96	0.92	0.89	0.87	0.90
ARA	0.85	0.92	0.98	0.93	0.95	0.95	0.93
AST	0.80	0.89	0.96	0.91	0.89	0.85	0.88
BAL	1.00	1.00	0.97	1.00	0.99	0.86	0.96
CAN	0.93	1.00	1.00	1.00	0.97	0.99	0.98
CANT	0.94	0.95	0.92	0.92	0.85	0.87	0.91
C y L	1.00	1.00	0.98	1.00	1.00	0.82	0.96
CLM	0.72	0.91	0.83	0.69	0.73	0.86	0.79
CAT	1.00	0.99	1.00	0.98	0.96	0.98	0.98
CV	0.88	0.93	0.95	0.92	0.95	0.86	0.91
EXT	0.73	0.79	0.82	0.79	0.85	0.84	0.80
GAL	0.76	0.96	0.97	0.87	0.93	0.93	0.91
MAD	1.00	1.00	1.00	0.98	1.00	0.99	0.99
MU	0.79	0.90	0.90	0.91	0.95	0.85	0.88
NAV	0.99	0.97	0.98	1.00	0.95	0.98	0.98
PV	0.92	0.96	0.97	1.00	0.96	0.99	0.99
LR	1.00	1.00	1.00	1.00	0.98	0.99	0.99
Obj.1	0.82	0.92	0.93	0.89	0.90	0.87	0.89
Rest	0.96	0.97	0.98	0.98	0.96	0.95	0.96
Total	0.89	0.95	0.95	0.94	0.93	0.93	0.93

tive 1 regions inside this group: Castilla y León y Comunidad Valenciana. These results could be related to the hypothesis of catching-up introduced in the standard growth literature.

Spanish regions defined as Objective 1 by the European Commission have been receiving Structural Funds since 1989. These funds clearly contribute to improve *core* and *non-core* infrastructures in these regions which benefits of them and could have an important effect. We include two programming periods of them inside our sample period: 1989-1993 and part of the second, 1994-1999 [7]. As we can see in Table 4, the efficiency score slightly increase in total Objective 1 regions during the 1989-1993 period (from 0.89 to 0.90). In some regions such as Castilla La Mancha, Extremadura and Murcia the increase is specially important. During the second programming period I observe a decrease in the average efficiency score of Objective 1 regions and only Castilla y León continues increasing.

4. Public capital effects on technical efficiency for Spanish regions

In this section I use an output-oriented FDH-VP to analyse the significance of public capital as an additional input in the production set. I estimate a baseline specification with GVA as output and labour (augmented by human capital accumulation) and private capital. Then, I also include among the inputs the stock of *core* (road and airports, harbours, railroads, water and electricity, telecommunications), *non-core* (education, hospitals and others) and total infrastructures. If infrastructures is a relevant input, the efficiency scores of the production set including their stocks should differ significantly from the baseline ones.

My results are included in Table 5. I show the regional mean scores (μ) over the six periods for the FDH-VP efficiency scores and the standard deviation (σ) in four different models: (i) A Baseline model which includes GVA as output and labour (augmented by human capital accumulation) and private capital, (ii) A Baseline + Core Infrastructures model, (iii) A Baseline + Non-Core Infrastructures and (iv) A Baseline + Total infrastructures model.

Table 5
Descriptive Statistics and Tests on the FDH-VP scores

Period		Baseline model		Baseline + Core infrastructure		Baseline + Non- Core infrastructure		Baseline + Total infrastructure
1965-69	μ	0.862	μ	0.886	μ	0.887	μ	0.888
	σ	0.103	σ	0.116	σ	0.115	σ	0.118
			T	0.16	T	0.18	T	0.11
			KS	0.066	KS	0.077	KS	0.067
1971-75	μ	0.933	μ	0.937	μ	0.945	μ	0.948
	σ	0.073	σ	0.070	σ	0.059	σ	0.054
			T	0.045	T	0.144	T	0.033
			KS	0.04	KS	0.18	KS	0.03
1977-81	μ	0.946	μ	0.950	μ	0.953	μ	0.955
	σ	0.066	σ	0.063	σ	0.059	σ	0.058
			T	0.035	T	0.156	T	0.049
			KS	0.039	KS	0.065	KS	0.049
1983-87	μ	0.928	μ	0.930	μ	0.934	μ	0.936
	σ	0.086	σ	0.085	σ	0.076	σ	0.074
			T	0.077	T	0.084	T	0.065
			KS	0.159	KS	0.065	KS	0.054
1989-93	μ	0.929	μ	0.931	μ	0.929	μ	0.935
	σ	0.069	σ	0.069	σ	0.065	σ	0.062
			T	0.006	T	0.113	T	0.049
			KS	0.038	KS	0.085	KS	0.025
1995-98	μ	0.911	μ	0.922	μ	0.927	μ	0.934
	σ	0.065	σ	0.065	σ	0.062	σ	0.062
			T	0.0012	T	0.012	T	0.0001
			KS	0.056	KS	0.039	KS	0.045

Proceeding in this way I can observe how the difference between mean scores, including core, non-core or both infrastructures in the production set, is. I use the T-statistic and the Kolmogorov-Smirnov (KS, henceforth) tests to check the significance of both infrastructures. In the first subsample, 1965-69, the core and the non-core infrastructures are not significant at the 5% level according to the T-test and the KS test. For 1971-75 period I find evidence of core infrastructures effects on technical efficiency using the T-test. When we consider the total infrastructures effects for that period I maintain my results. During the transition period, 1977-81, both tests indicate again evidence in favour of core infrastructure effects. For the 1983-87 period I observe a weak evidence (10% level) using both types of tests for core and non-core infrastructures. In the 1989-93 period I find evidence in favour of core infrastructures and total infrastructures but not for non-core infrastructures. Finally, I check both infrastructures effects for the 1995-98 period and I clearly accept their effects on technical efficiency using the T-test. If I also test the null hypothesis of a larger effect for core infrastructures than for non-core infrastructures we cannot reject it with a p-value of 0.0525 using a T-test [8].

Next, I repeat the same exercise within a sub-sample composed by Objective 1 regions. The derived results are offered in Table 6 and they are slightly similar to the above mentioned results in Table 5 except for the 1965-69 period. I observe an opposite effect during that period because the core and the non-core infrastructures are significant at the 5% level according to the T-test and the KS test. In the second sub-sample, 1971-75, I find evidence of both core and non-core infrastructures effects on technical efficiency using the T-test and KS-test while I only derived core infrastructures effects in the previous exercise. During the transition period (1977-81), we only observe again evidence in favour of core infrastructure effects. Nevertheless, this effect is larger than that obtained including the rest of regions. For

Table 6
Descriptive Statistics and Tests on the FDH-VP scores in Objective 1 regions

Period	Baseline model		Baseline + Core infrastructure		Baseline + Non- Core infrastructure		Baseline + Total infrastructure	
1965-69	μ	0.812	μ	0.815	μ	0.814	μ	0.823
	σ	0.107	σ	0.104	σ	0.107	σ	0.118
			T	0.025	T	0.026	T	0.114
			KS	0.010	KS	0.011	KS	0.047
1971-75	μ	0.868	μ	0.903	μ	0.919	μ	0.918
	σ	0.091	σ	0.075	σ	0.067	σ	0.079
			T	0.002	T	0.004	T	0.002
			KS	0.008	KS	0.002	KS	0.008
1977-81	μ	0.918	μ	0.924	μ	0.929	μ	0.926
	σ	0.077	σ	0.074	σ	0.071	σ	0.077
			T	0.004	T	0.138	T	0.009
			KS	0.046	KS	0.097	KS	0.108
1983-87	μ	0.891	μ	0.893	μ	0.901	μ	0.903
	σ	0.099	σ	0.100	σ	0.088	σ	0.099
			T	0.31	T	0.070	T	0.26
			KS	0.108	KS	0.086	KS	0.127
1989-93	μ	0.908	μ	0.911	μ	0.909	μ	0.907
	σ	0.080	σ	0.081	σ	0.073	σ	0.081
			T	0.253	T	0.813	T	0.341
			KS	0.10	KS	0.33	KS	0.14
1995-98	μ	0.878	μ	0.891	μ	0.897	μ	0.908
	σ	0.055	σ	0.058	σ	0.053	σ	0.055
			T	0.017	T	0.004	T	0.01
			KS	0.007	KS	0.002	KS	0.004

the 1983-87 period I do not observe a weak evidence (10% level) using both types of tests for core and non-core infrastructures and, within this sub-sample, I completely reject some infrastructure effect on technical efficiency. In the 1989-93 period, I find evidence in favour of core infrastructures and total infrastructures but not for non-core infrastructures. Finally, I check both, core and non-core, infrastructures effects for the 1995-98 period and I find larger effects on technical efficiency, using both T-test and KS-test, than the derived for all the Spanish regions in Table 5.

All in all, this non-parametric technique finds evidence in favour of the role developed by core infrastructures in the public capital impact on productivity in the majority of periods. However, the results offered in Table 6 shows that this impact is generally stronger in the less developed Spanish CC.AA than the rest of them. I do not observe an important effect for non-core infrastructures except for the 1965-69, 1977-81 and 1995-98 in Objective 1 regions. If we add the rest of regions we only observe non-core infrastructure effects during the 1995-98 period. These results could be explained because infrastructure stocks have not yet reached an adequately high level at which some sort of saturation effect may set in, specially in Objective 1 regions.

4.1. Checking robustness: lagged effects for public capital

As suggested by Munnell (1992), to reduce the possibility of any feedback effect of private-sector output on the stock of public capital I measure technical efficiency with core, non-core and total infrastructures lagged one period.

Results in Table 7, support the hypothesis of a positive and significative impact for core infrastructures. This effect is not larger than the obtained by using the contemporaneous value of public infrastructure in Table 5.

As regards the exercise for Objective 1 regions I do not report results to save space. There are no differences again with the estimates obtained in Table 6 for Objective 1 regions using the contemporaneous value [9].

5. Conclusions

This paper contributes to the empirical literature on public capital effects on Spanish regions productivity by applying an alternative approach to examine its effects based on a non-parametric FDH production technology. Most previous empirical studies of the effect of public capital on aggregate real private output have reported estimates of average production functions. A number of those studies concluded that public capital increases real private output but in the context of a model in which public capital is included as a conventional input in the production function, along with private capital and labour. The main problem in these studies is the omitted potential role for public capital in reducing the technical inefficiency of private-sector production. Consequently, the stochastic structure of these models may have been misspecified, calling into question the conclusions based on their estimates.

Table 7
Descriptive Statistics and Tests on the FDH-VP scores with a lag in public capital effects

Period	Baseline model		Baseline + Core infrastructure		Baseline + Non- Core infrastructure		Baseline + Total infrastructure	
1965-69	μ	0.887	μ	0.886	μ	0.892	μ	0.892
	σ	0.114	σ	0.116	σ	0.105	σ	0.103
			T	0.21	T	0.50	T	0.21
			KS	0.066	KS	0.17	KS	0.067
1971-75	μ	0.934	μ	0.936	μ	0.945	μ	0.948
	σ	0.073	σ	0.070	σ	0.059	σ	0.054
			T	0.045	T	0.15	T	0.045
			KS	0.04	KS	0.20	KS	0.1275
1977-81	μ	0.944	μ	0.949	μ	0.954	μ	0.955
	σ	0.070	σ	0.066	σ	0.060	σ	0.058
			T	0.036	T	0.058	T	0.007
			KS	0.038	KS	0.038	KS	0.049
1983-87	μ	0.929	μ	0.930	μ	0.935	μ	0.936
	σ	0.085	σ	0.084	σ	0.076	σ	0.074
			T	0.098	T	0.121	T	0.079
			KS	0.059	KS	0.088	KS	0.056
1989-93	μ	0.929	μ	0.933	μ	0.930	μ	0.935
	σ	0.069	σ	0.066	σ	0.065	σ	0.062
			T	0.007	T	0.29	T	0.29
			KS	0.0417	KS	0.092	KS	0.056
1995-98	μ	0.911	μ	0.922	μ	0.928	μ	0.934
	σ	0.065	σ	0.066	σ	0.062	σ	0.062
			T	0.0012	T	0.022	T	0.022
			KS	0.0423	KS	0.0597	KS	0.0597

All in all, the main two advantages of this approach are: (i) it allow us to relax the assumptions of constant returns to scale and a given functional form used in a «growth accounting» methodology or traditional convergence regressions and (ii) it jointly considers the public capital effects in reducing technical inefficiency of private-sector production and as a conventional input in the production function.

The results shows that the effect of public capital is strong and specially important in less developed regions. I also show that the core infrastructures are the most important input when I consider a public capital contemporaneous or lagged effect. These important effects could imply that infrastructure stocks have not yet reached an adequately high level at which some sort of saturation effect may set in.

Further research should be carried out on several fronts. One is revisit these conclusions adopting panel data techniques (Im *et al.,* 2001) to show that technical efficiency is positively correlated with the stock of public capital or infrastructure. As Delorme *et al.* (1999) point out, we could estimate a production frontier which includes a public capital variable and test their effects on private productivity. Following this procedure we could differentiate direct public capital effects (increasing output) and indirect effects (improving technical efficiency). We also could use this non-parametric set-up based on a VP-FDH to analyse the effect of other important inputs.

Notas

1. See in Boldrin and Canova (2001) and references provided by these authors a detailed discussion on this topic.
2. The sensitivity of the empirical results on the functional form assumptions has been forcefully voiced within this literature by Gramlich (1994).
3. See in Henderson (2003) a comparison of these deterministic techniques and a survey about the developments and extensions of technical efficiency measurement using panel data.
4. The data for capital stock and human capital are obtained from Más, Maudos, Pérez and Uriel (1999) and Más, Pérez, Serrano and Soler (2002).
5. I also tried two additional measures of human capital taken from Psacharopoulos (1992) and Aller and Arce (2001). In the first one Mincerian coefficients were 0,172 for «1-3.5» years, 0.086 for «3.6-11» years and 0.128 for «12-». The second one considers a return to average schooling different across regions through the estimated Mincer earning equations for Spanish regions divided by female and male employees. Using these alternative measures did not yield results appreciably different from those which we report.
6. Pedraja *et al.* (2002) also derived, using a Malmquist index for the sample period 1965-95, the highest efficiency scores for Madrid (1.00) and País Vasco (0.96) and the lowest for Extremadura (0.69) and Castilla-La-Mancha (0.72).
7. My results are similar to ones derived by Puigcerver (2004) for both programming periods using panel data techniques.
8. The T-test is a paired samples t-test. I also use the KS-test although is notoriusly less powerful than the t-test.
9. The results using lagged effects for public capital on Objetive 1 regions are available upon request.

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Resumen

Este trabajo considera un metodología no-paramétrica novedosa, la *Variable Parameters- Free Disposal Hull (VP-FDH)* originalmente propuesta por Kersten and Vanden Eeckaut (1999), con el fin de analizar los efectos del capital público sobre la productividad de las CC.AA. españolas. Este método tiene grandes ventajas para comparaciones de productividad a nivel regional y, en general, en aquellos casos en los que el supuesto de convexidad en el conjunto de producción parece no ser apropiado. Los resultados obtenidos muestran que el capital público ha tenido un impacto significativo en las regiones españolas menos desarrolladas. Al realizar una desagregación en infraestructuras «comunes» y «no-comunes» se observa que el papel del primer grupo de infraestructuras ha sido más relevante durante el período objeto de análisis.

Palabras clave: productividad regional, eficiencia tecnológica, capital público, convexidad.

Clasificación JEL: C31, O47.